

[0013] As can be seen in FIGS. 1 and 7, bending or deformation of the top conductive layer is heavily dependent on the mechanical conditions and location of the bending surface. The same force applied in the middle of the sensor area would produce a different degree of deformation as compared to the deformation at the edge of the sensor area. This difference in deformation depending on a particular location of where the deforming force is applied is one of the key factors why this type of sensor has not been used in applications where there is no consistently flat surface available for reliable sensor operation. Prior art in deformable touch sensors describes them as stand-alone components that can be incorporated in various devices because the touch-sensitive area is flat and so achieving uniform response is relatively easy.

[0014] Housing of an electronic device on the other hand typically has a highly complicated and curved surface as can be easily appreciated by observing various typical examples of these devices like cell phones, PDAs, music players, etc. Due to their small size, it is desirable to extend user input area into curved areas of the housing. Curvature of these surfaces would make the operation of the touch sensor of the first type questionable as it still relies on consistent deformation in various places thereof in response to the same force applied over various locations.

[0015] The present invention addresses the above need by providing a housing for an electronic device with integrated proportional user input capability. More specifically, disclosed herein is a sensing device where the electronic housing itself (which is either made from metal or has an inside conductive surface) is used as a deformable structure for a tactile sensor device. A capacitance force sensor is created between the conductive inside surface of the housing serving as a first conductive layer and a rigid non-deformable base having a second conductive layer facing the first conductive layer and spaced apart therefrom at a predetermined gap. This pair of conductive layers separated by a dielectric layer containing a non-conductive material, such as air, together makes a capacitance sensor. Compression of the housing deforms the first conductive layer and brings it closer to the second conductive layer changing therefore the level of capacitance therebetween. This in turn allows for capacitance-based electrical detection of both the event of user-applied pressure or force on a selected user input zone of the housing as well as the level of force applied to the housing. Both the event of compression of the housing in a particular location and the degree of this compression can be used as user input signals for the electronic device.

[0016] In comparison with traditional membrane switches, this invention allows the product design to be clean and free of lines and seams associated with conventional buttons. In contrast to recently popular touch switches that detect the presence of a human finger or a conductive object, this approach is also able to work with non-conductive objects such as a person wearing a glove and measure the level of force applied by the user in a proportional sense.

[0017] Prior art resistive touch screens are flat and use two transparent conductive layers that deform with applied pressure. They have not been implemented into a complex curved shape such as a seamless electronic housing. They also have not been able to measure proportional force that is applied onto them since the physical contact between the two layers needs to occur for it to provide an input signal. By sensing the capacitance between the two electrodes, a proportional analog signal can be measured and smaller amounts of deflections

can be used to provide a more robust seamless housing design in comparison to resistive touch screens. The input of the present invention also does not have to have a flat surface or noticeable surface transitions as present in membrane switches.

[0018] More recently, manufacturing process have developed methods allowing metalization of the inside and embedded into the housing, even if the housing is very organic and curved in shape, for example a co-laminated/molded process or pre-printed and then formed process such as RF antennas and metallic decorative prints. This allows more flexibility in defining the location, shape, and grounding methods of the electrode embedded into the housing versus the traditional spray and sputtered coated processes.

[0019] Implementation of this invention requires availability of a sensitive capacitance sensing circuit that can detect very small (less than 0.001") deflections in the housing as well as an integrated sensor housing design that controls deflection levels, peak versus average deformation, cross talk between adjacent elements, compensation for sensitivity differences between the center of the housing versus the corner, etc.

[0020] By adjusting the thickness of the housing, an aluminum cover can be made to deflect identically to ABS cover. If the ABS cover has uniform thickness of 1.00 mm, the corresponding thickness values for aluminum cover are 0.31 mm, following a rule that displacement results are consistent for constant values of the product Et^3 , where E is the modulus of elasticity of the cover material and t is the cover thickness.

[0021] For one particular housing configuration, when a force of 4.0 N is applied over a circle 7 mm in diameter, centered over one input zone, the maximum deflections were approximately 0.5 thousandth of an inch and an average deflection over the input zone was 0.2 thousandths of an inch.

[0022] This invention may be used advantageously with reconfigurable or other tactile sensor input devices disclosed elsewhere by the same inventor and also those that are known in the art. It can also be configured to work together with a vibration or tactile feedback mechanism where the activation threshold of a button is software-controlled. This allows a strong person to set the activation level at a higher force level than a person with more gentle touch or to adjust the activation threshold based on the amount of sensed acceleration due to activity.

[0023] This invention can be used to replace or improve the following technologies and devices:

[0024] Discrete button switches that at present require separate components and are only binary;

[0025] Mechanical dome switches located under compliant skin or other flexible membranes;

[0026] Touch pads on laptops that at present only detect contact location and not force;

[0027] Ipad scroll wheel that at present does not detect force;

[0028] Side keys on a phone; and

[0029] Analog joysticks such as found on a Thinkpad Laptop

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] A more complete appreciation of the subject matter of the present invention and the various advantages thereof can be realized by reference to the following detailed descrip-